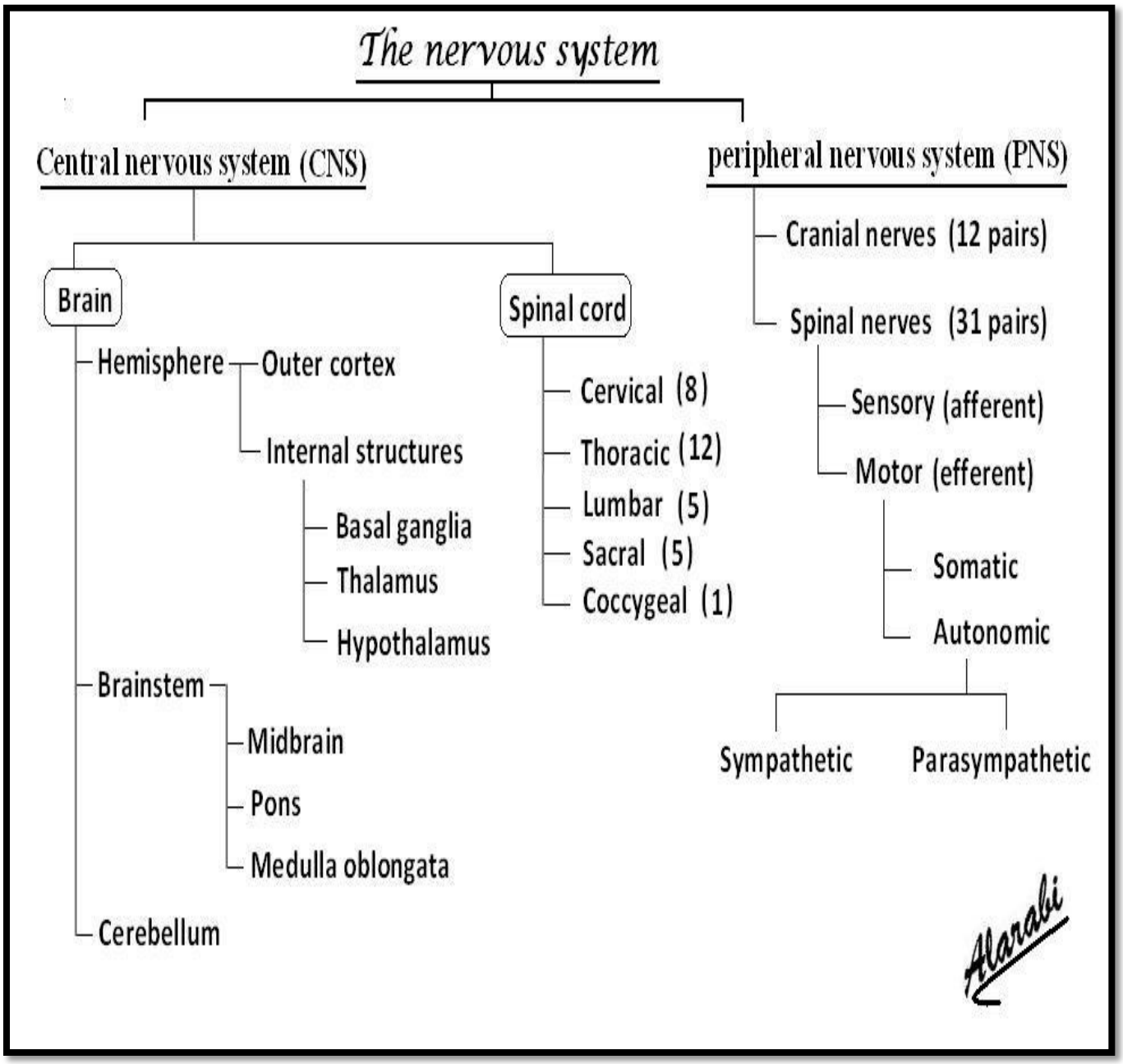
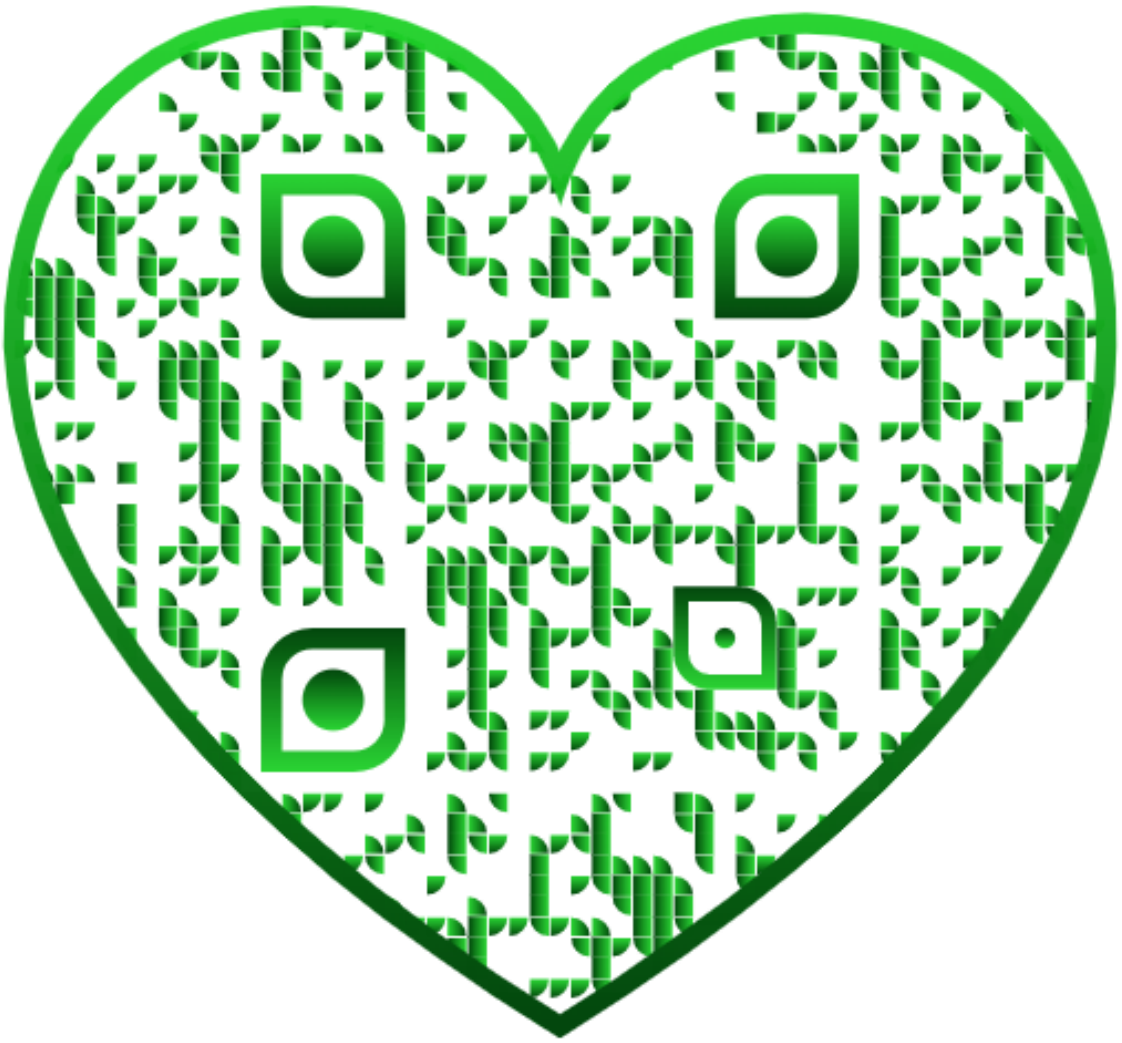
The Autonomic Nervous System

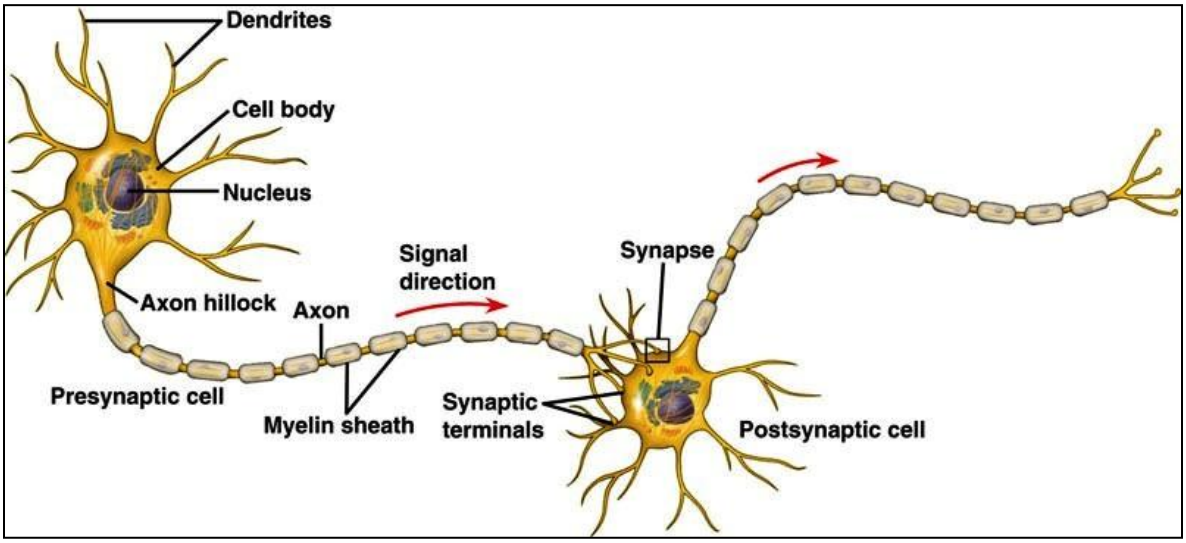




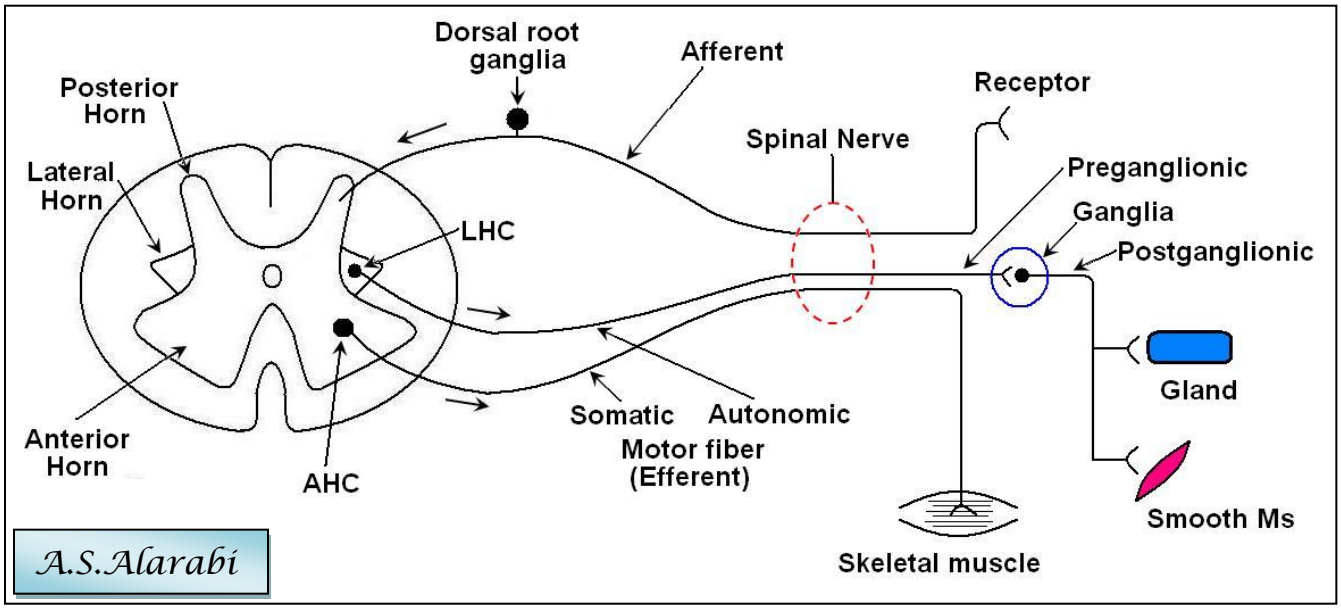
Introduction to the nervous system

The nervous system is composed of an anatomical unit (*Neuron*) and functional unit (*Reflex*).

1] ***Neuron***: It is the anatomical (structural) unit of the nervous system.
It will be discussed in (Nerve & Muscle) chapter.



2] ***Reflex***: It is involuntary action that occurs in response to a stimulus.
It is mediated by the *Reflex Arc*. The pathway of the reflex arc is composed of:



a- ***Receptor***: It is a specialized structure sensitive to minor changes outside or inside the body (*sensitive to stimulus*).

b- ***Afferent (Sensory) neuron***: It carries the impulses from a receptor to CNS. Its mother cell is located in dorsal root ganglion.

c- ***Center***: It is present in the CNS. It could be an interneuron or a cell body [e.g. Anterior Horn Cell (AHC) in somatic reflexes].

d- ***Efferent (Motor) neuron***: It carries impulse from CNS to the Effector Organ. Its mother cell is located either in [Anterior Horn (AH) in case of somatic reflex] or in [Lateral Horn (LH) in autonomic reflex].

e- ***Effector organ***: It is the structure that produces response (i.e. Skeletal, smooth and cardiac muscles / Glands)

So, the reflex is classified according to the response into [*Somatic* & *Autonomic*].

	***Somatic* reflex arc**	***Autonomic* reflex arc**
Receptor	The same	
Afferent	The same	
Center	Anterior Horn Cell (AHC)	Lateral horn cell (LHC)
Efferent	One neuron	Two neurons synapse at ganglia: a- *preganglionic*: its mother cell in LH. b- *postganglionic*: its mother cell in ganglia
Effector organ	Skeletal muscle	Smooth or Cardiac Muscle / Glands.

The Autonomic Nervous System

It is the part of N.S that controls the involuntary activity of the body. It is divided into two divisions [***Sympathetic* & *Parasympathetic***].

Anatomically, the relation between these 2 divisions is *double innervations* (i.e. most organs are innervated by both *Symp*. & *Parasymp*). *Exceptionally*, some organs have only sympathetic *(Single) innervations* which are:

[Skin / Adrenal medulla / Spleen / Ventricles of the Heart, Blood Vessels of Skeletal Muscles of (Limbs / Abdominal & Thoracic wall)].

Functionally, the relations between 2 divisions are:

- ***Antagonism*:** It's the main relation; when one division is *Excitatory* to (stimulate) certain organ, the other division is *Inhibitory* (inhibit it) [e.g. sympathetic ↑ heart rate while parasympathetic ↓ it].
- ***Synergism*:** Exceptionally, the 2 divisions may help each other.
- ***Similarity*:** Exceptionally, the 2 divisions may have similar action on the same organ (e.g. stimulation of salivary secretions).
- ***Dominance*:** During rest, one division is dominant to some organs tone [mild continuous activity during rest (e.g. Symp. vasoconstriction)].
- ***Reciprocal action*:** When one division is stimulated, the other is inhibited.

The *Preganglionic* and *Postganglionic* neurons of both (Symp & Parasymp) connecting (synapsing) at an area called *Ganglia*. The *ganglion* is a collection of nerve cell bodies outside the CNS. It acts as a distributing center (diversion of neurons), i.e. one *Preganglionic* fibers synapsing with many *Postganglionic* fibers.

Note: The *Adrenal Medulla* is considered as autonomic ganglia, because it's exceptionally supplied by *preganglionic* sympathetic fiber (no postganglionic fiber).

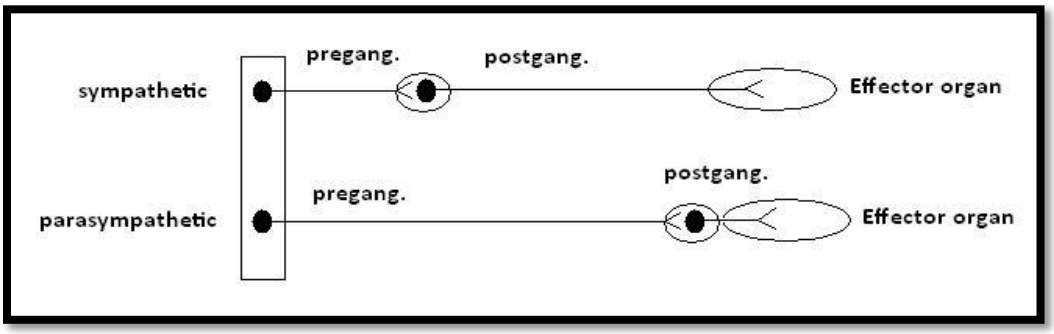
► The ganglia are classified according to their location into 3 types:

1- ***Lateral (paravertebral)***: they are on the sides of vertebral column, they are sympathetic only. They form the *sympathetic chain*, where each chain is formed of 26 ganglia [3 *Cervical*, 12 *Thoracic*, 5 *Lumbar*, 5 *Sacral* and 1 *Coccygeal*].

2- ***Collateral*** *(prevertebral)*: They lie midway between spinal cord and visceral organs at origin of big arteries from aorta. They are mixed sympathetic and parasympathetic.

3- ***Terminal:*** they lie within the innervated organ (organ of supply). They are only parasympathetic.

Note: as the sympathetic ganglia (lateral) located near the spinal cord, and the parasympathetic ganglia (terminal) located far from the spinal cord; so, the preganglionic neurons are shorter than the postganglionic neurons (in the sympathetic), and longer (in the parasympathetic).



	Sympathetic	***Parasympathetic***
Origin	*Thoracolumbar* •All the thoracic segments of the spinal cord (T1 – T12). •Upper 3 lumbar segments (L1 – L3).	*Craniosacral* •Cranial nerves (3, 7, 9, 10) •Middle 3 sacral segments (S2 – S4).
Ganglia	Lateral & collateral	Terminal & collateral
Active during	Stress & Emergency (exercise, fear, fight, escape, exam).	It is active during rest (relaxation).
Action	Prepares the body for ↑ activity It is catabolic (energy consuming).	Prepares the body for recovery and repair It is anabolic (energy preserving).
Activity type	Generalized (mass discharge).	Localized (each part act separately). Generalized parasymp. Stimulation can be fatal

Effects of Sympathetic & Parasympathetic on various tissues

Effect	Sympathetic	Parasympathetic
Eye	• Pupil dilatation (mydriasis). • ↓ Lens power. • Elevation of upper eyelid • Exophthalmos	• Pupil constriction (miosis). • ↑ Lens power.
Salivary gland	• ↓ saliva (stimulate secretion of viscid saliva).	• ↑ saliva (stimulate secretion of true saliva).
Skin	• Vasoconstriction. • Contraction of piloerector muscle. • Stimulate sweating.	• No known effect.
Heart	• ↑ Heart rate & force of contraction. • Coronary vasodilatation.	• ↓ Heart rate and force of contraction. • Coronary vasoconstriction.
Lung	• Bronchodilataion.	• Bronchoconstriction.
GIT	• GIT wall relaxation & GIT sphincters contraction → ↓ GIT motility & secretion.	• GIT wall contraction & GIT sphincters relaxation → ↓ GIT motility & secretion
Defecation	• Inhibit defecation	• Stimulate defecation
Urinary bladder	•Relaxation of bladder wall and Contraction of bladder sphincters → ↓ Urination	• Contraction of the bladder wall. and Relaxation of bladder sphincter → ↑ Urination
Blood vessels	• Vasoconstriction in all vessels except [brain, heart, skeletal muscles].	• Little vasodilator effect.
Adrenal medulla	• Stimulate secretion of Adrenaline and Noradrenaline.	• No effect.
Metabolism	• Hyperglycemic (diabetogenic) effect [inhibit insulin secretion, glycogenolysis, lipolysis, etc].	• Hypoglycemic effect [stimulate insulin secretion].
Other effects	• Contraction of spleen • Glycogenolysis & Lipolysis	• ↑ Lacrimal & Nasal Secretions. • Vasodilatation of Tongue.

● The neurotransmitters & receptors in the A.N.S:

	Sympathetic	Parasympathetic
Neurotransmitter	•The preganglionic fibers are cholinergic. •The postganglionic fibers are adrenergic, except that go to the following, which are cholinergic: **a**- Sweat glands. **b**- Smooth muscles of blood vessels.	•All the pre and postganglionic fibers are cholinergic.
Receptors **At Ganglia**	• *Cholinergic* (Nicotinic) receptors.	• *Cholinergic* (Nicotinic) receptors.
At Effector organ	• *Adrenergic* [α (α1 /α2), & β (β1/ β2)] at most tissues. • *Cholinergic* (Muscarinic) at [sweat glands & smooth muscles of blood vessels].	• *Cholinergic* (Muscarinic).

Note: • **β1** are *Excitatory* and present only in the heart [↑ HR].

• **β2** are *Inhibitory* and causes vasodilatation & Relaxation of [Uterus, GIT & Urinary Bladder *wall*, Bronchial smooth muscles].

• **α1** are *Excitatory* and causes vasoconstriction and contraction of [Dilator Pupillae ms, Piloerector ms. of hair, and GIT & Urinary Bladder *sphincters*].

• **α2** are *Inhibitory* and present only in GIT wall causing its dilatation.

Mass discharge of the sympathetic N.S

The sympathetic nervous system is usually activated by the hypothalamus *all as one unit*. This occurs in cases of stress, either *mental* [e.g. *Fear*, *Exam*, *embarrassment*, etc] or *physical* [e.g. *Exercise*, *Escape*, *Fight*].

The effects of this mass discharge of the sympathetic division prepare the body for these situations. These effects include:

1- *Pupil dilatation* [to increase the visual field].

2- *Bronchodilatation* [for hyperventilation to provide more oxygen].

3- *Stimulate the adrenal medulla* [to provide more adrenaline and noradrenaline to potentiate its effect].

4- *Squeezing the spleen capsule* → Pumping a 1/2 Letter of blood into circulation.

5- ↑ the heart rate and force of contraction [to deliver more blood to organs in need].

6- Stimulate *glycogenolysis* and *lipolysis* [to ↑ energy source].

7- ↑ the blood flow to the active areas. This is done by *vasoconstriction* of the blood vessels in the *non active areas* [e.g. *Skin*, *GIT*, *Bladder*, etc] and shifting this blood to the *vasodilated* vessels of the active areas [e.g. Heart, Brain, Skeletal muscles].

Note: the *Adrenaline* (Epinephrine) and *Noradrenaline* (norepinephrine) have similar effect, except that *Adrenaline* is more potent on the heart and metabolism, while *Noradrenaline* is more potent on blood vessels (vasoconstriction).

Horner's syndrome

It is a group of manifestations results from interruption of the sympathetic supply to the Head & Neck (the manifestations appear on the same site of lesion).

These manifestations include:

- *Ptosis* (drop of upper eyelid)
- *Miosis* (narrowing of pupil)
- *Enophthalmos* (posterior displacement of eyeball)
- *Anhydrosis* (loss of sweating)
- *Flushed skin* (warm red skin)

The chemical transmitters of the ANS

I – Acetyl choline (Ach or A.C):

This neurotransmitter is synthesized at nerve terminals as the following:

Acetate + Coenzyme A ⟶ *Acetyl-CoA.*

Acetyl-CoA + Choline ⟶ *Acetyl choline + CoA.*

After its release and action, the *Ach* is removed mainly by enzymatic destruction by the ***choline esterase*** enzyme. A small amount is removed by *diffusion* to surrounding tissue, or *reuptaked* by nerve terminals.

Acetyl choline $\xrightarrow{\text{Cholinesterase}}$ **choline + acetic acid**

The acetyl choline is formed and released from nerve terminals (synaptic knobs) of cholinergic fibers at the following sites:

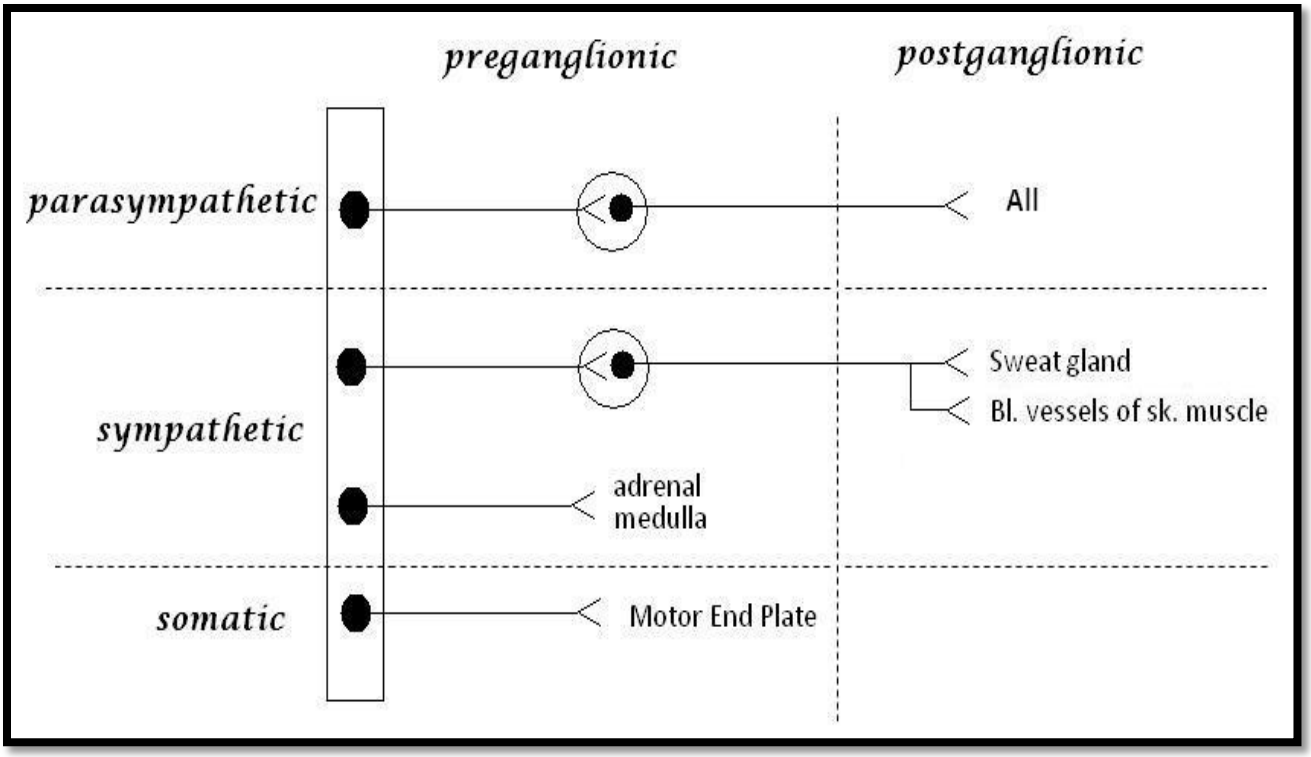
1- *Autonomic ganglia* of both sympathetic and parasympathetic divisions.

2- All *postganglionic parasympathetic* fibers.

3- The postganglionic sympathetic fibers that innervate [*Sweat glands* / *Bl vessels of Skeletal Muscles*].

4- The preganglionic sympathetic fibers to the *Adrenal Medulla*.

5- The *motor end plate* at skeletal muscles [somatic not autonomic].



The cholinergic receptor could be affected by administration of drugs.
These drugs may:

1- *Stimulate* the cholinergic receptors (*parasympathomimetics*). They include:

a- Dugs has similar action to Ach [e.g. ***Methacholine***, ***Pilocarpin***, ***Nicotine*** (small dose)].

b- *Anticholineesterases* [e.g. ***Neostigmine***, ***Prostigmine***].

2- *Inhibit* the cholinergic receptors (*parasympatholytics*). They include:

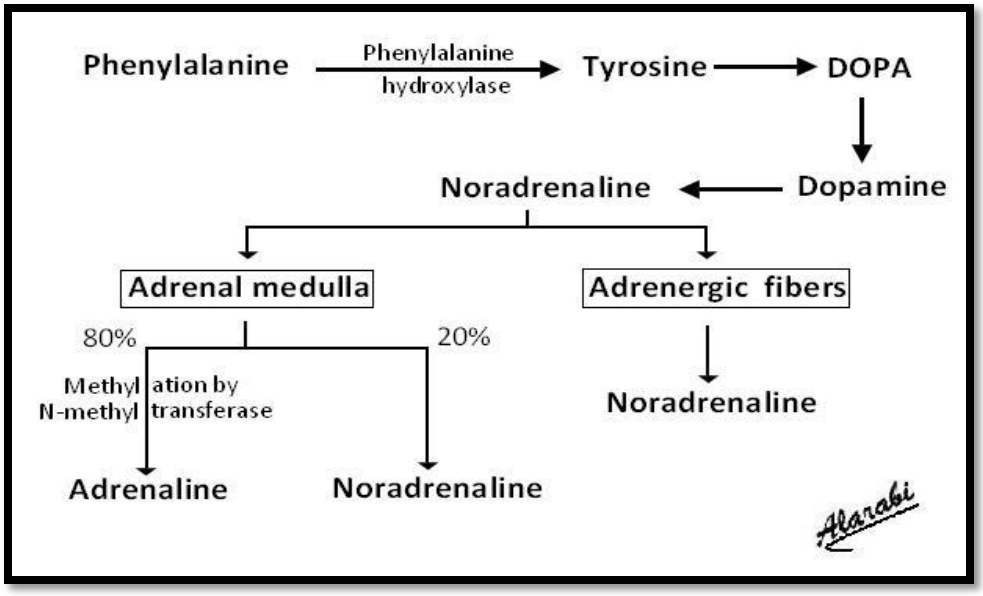
a- *Anticholinergics* [e.g. ***Atropine***, ***Homatropine***].

b- *Ganglion blockers* [***Hexamethonium***, ***Nicotine*** (large dose)].

c- *Neuromuscular blockers* [e.g. ***Curare***, ***Succinyl choline***].

II – Noradrenaline (Norepinephrine) (N.A):

The *N.A* is synthesized at nerve terminal of adrenergic neurons as the following:



♦ In the Adrenal Medulla, 80% of the Noradrenaline converts into adrenaline by the action of *N-methyl transferase* enzyme which is not present at nerve terminals, thus Adrenaline is formed only in adrenal medulla.

♦ The *N.A* is removed mainly (50-80 %) by *active reuptake* to the nerve terminals. The remaining small amount of N.A is removed by:

1- Enzymatic destruction: it is either by:

a- *Oxidation: by monoamine oxidase* ***(MAO)*** *enzyme.*

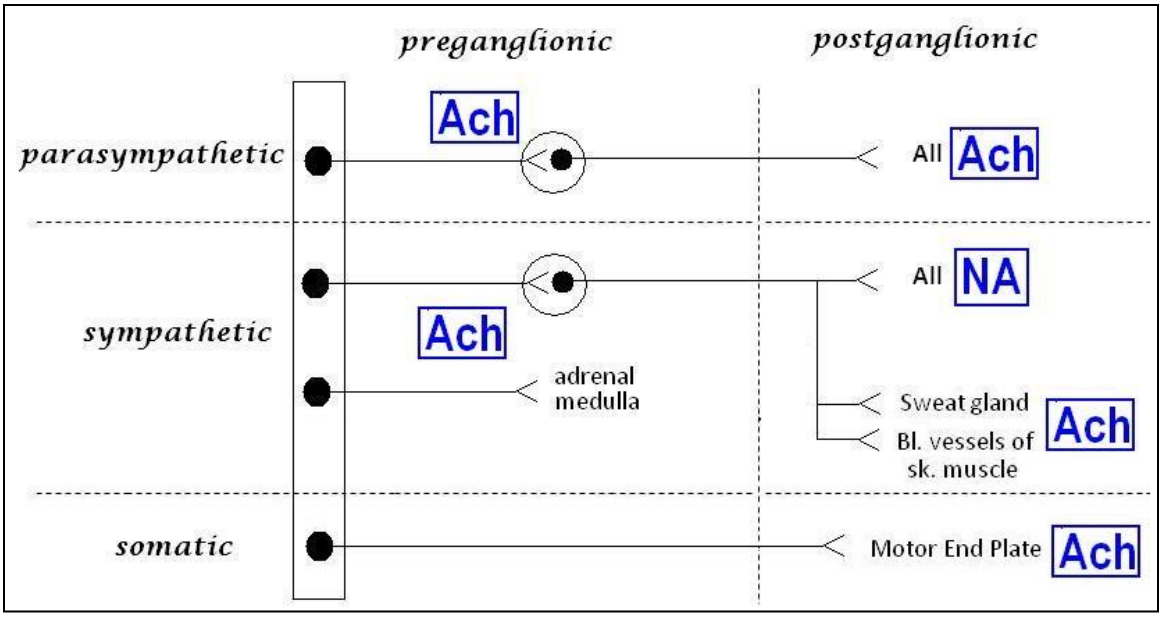
b- *Methylation: by catechol-O-methyl transferase* ***(COMT)*** *enzyme.*

2- *Diffusion* to surrounding tissues.

♦ The *N.A* is released from the following sites:

1- End of all *postganglionic sympathetic* fibers [Except the 2 cholinergic fibers].
2- The Adrenal Medulla secretes Noradrenaline (20%) and Adrenaline (80%).
3- *N.A* acts as *neurotransmitter* inside the CNS.

Note: ***Alpha*** receptors are more sensitive to *NA > ADR*, while ***Beta*** are equally sensitive to *NA & ADR*.



The adrenergic pharmacology:

Site of action	Stimulants	Inhibitors
Release of N.A from postganglionic fibers	[*Ephedrine - Amphetamine*]	[*Reserpin – Guanithidine*]
Alpha receptors (α)	[*N.A – ADR - Phenylephrine*]	[*Phentolamine – Ergot alkaloids*]
Beta receptors (β)	[*Isoprenaline - ADR*]	[*Propranolol*]

With my Best Wishes

Dr. Ahmad Alarabi

2015 - 2016